Sleep Medicine Reviews 18 (2014) 415–424

Contents lists available at ScienceDirect

Sleep Medicine Reviews

journal homepage: www.elsevier.com/locate/smrv

CLINICAL REVIEW

# The evidence base of sleep restriction therapy for treating insomnia disorder

Christopher B. Miller [a,b,*], Colin A. Espie [c], Dana R. Epstein [d,e], Leah Friedman [f,g], Charles M. Morin [h], Wilfred R. Pigeon [i,j], Arthur J. Spielman [k,l], Simon D. Kyle [m]

[a] Centre for Integrated Research and Understanding of Sleep (CIRUS), Woolcock Institute of Medical Research, Sydney Medical School, University of Sydney, Australia
[b] Institute of Neuroscience & Psychology, University of Glasgow, UK
[c] Nuffield Department of Clinical Neurosciences and Sleep & Circadian Neuroscience Institute, University of Oxford, UK
[d] Phoenix Veterans Affairs Health Care System, USA
[e] Arizona State University College of Nursing and Health Innovation, USA
[f] Department of Psychiatry and Behavioral Sciences, Stanford University, Palo Alto, USA
[g] Veterans Affairs Palo Alto Health Care System, Palo Alto, CA, USA
[h] Université Laval, Québec City, Québec, Canada
[i] Sleep & Neurophysiology Research Lab, University of Rochester Medical Center, USA
[j] Center of Excellence for Suicide Prevention, U.S. Department of Veterans Affairs, USA
[k] Cognitive Neuroscience Doctoral Program, The City College of the City University of New York, USA
[l] Weill Cornell Medical College, Center for Sleep Medicine, NY, USA
[m] School of Psychological Sciences, University of Manchester, UK

ARTICLE INFO

*Article history:*
Received 11 October 2013
Received in revised form
19 January 2014
Accepted 30 January 2014
Available online 12 February 2014

*Keywords:*
Insomnia
Sleep
Cognitive behavioral therapy
Treatment
Psychological intervention
Sleep restriction therapy
Evidence base
Review

SUMMARY

Sleep restriction therapy is routinely used within cognitive behavioral therapy to treat chronic insomnia. However, the efficacy for sleep restriction therapy as a standalone intervention has yet to be comprehensively reviewed. This review evaluates the evidence for the use of sleep restriction therapy in the treatment of chronic insomnia. The literature was searched using web-based databases, finding 1344 studies. Twenty-one were accessed in full (1323 were deemed irrelevant to this review). Nine were considered relevant and evaluated in relation to study design using a standardized study checklist and levels of evidence. Four trials met adequate methodological strength to examine the efficacy of therapy for chronic insomnia. Weighted effect sizes for self-reported sleep diary measures of sleep onset latency, wake time after sleep onset, and sleep efficiency were moderate-to-large after therapy. Total sleep time indicated a small improvement. Standalone sleep restriction therapy is efficacious for the treatment of chronic insomnia for sleep diary continuity variables. Studies are insufficient to evaluate the full impact on objective sleep variables. Measures of daytime functioning in response to therapy are lacking. Variability in the sleep restriction therapy implementation methods precludes any strong conclusions regarding the true impact of therapy. A future research agenda is outlined.



**Sleeping is no mean art: for its sake one must stay awake all day. – Friedrich Nietzsche**

Sleep restriction therapy (SRT) is a behavioral intervention that is used to treat chronic insomnia [1,2], either as single component therapy, or as part of cognitive behavioral therapy for insomnia (CBT-I) [3,4]. Anecdotally, SRT is believed to be one of the most active elements of CBT-I. Indeed, Spielman et al. [5], emphasize the importance of SRT in an overview of 12 CBT-I trials, where all trials incorporated SRT procedures. However, the first American Academy of Sleep Medicine (AASM) practice parameters for the non-pharmacologic treatment of chronic insomnia considered SRT to be an optional patient-care strategy whereby, "patient improvement was unclear due to combination therapy" [6, p. 1131]. The most recent update of the AASM practice parameters suggest that SRT should be considered a "guideline" intervention due to the addition of two randomized controlled trials [2,7]. This is one step below

* Corresponding author. Woolcock Institute of Medical Research, Sydney Medical School, University of Sydney, PO Box M77, Missenden Road, Sydney, NSW 2050, Australia. Tel.: +61 (2) 9114 0451; fax: +61 (2) 9114 0014.
*E-mail address:* chris.miller@sydney.edu.au (C.B. Miller).

http://dx.doi.org/10.1016/j.smrv.2014.01.006
1087-0792/

**Abbreviations**

| | |
|---|---|
| AASM | American Academy of Sleep Medicine |
| APA | American Psychological Association |
| CBT-I | cognitive behavioral therapy for insomnia |
| CS | case study |
| EEG | electroencephalography |
| ES | effect size |
| ESS | Epworth sleepiness scale |
| GSES | Glasgow sleep effort scale |
| ISI | insomnia severity index |
| ISQ | insomnia symptom questionnaire |
| MSLT | multiple sleep latency test |
| NOA | number of awakenings |
| NRCT | non-randomized control trial |
| PSG | polysomnography |
| PSQI | Pittsburgh sleep quality index |
| PVT | psychomotor vigilance task |
| RCT | randomized control trial |
| REM | rapid eye movement |
| SCT | stimulus control therapy |
| SE | sleep efficiency |
| SOL | sleep onset latency |
| SQ | sleep quality |
| SSS | Stanford sleepiness scale |
| SWS | slow wave sleep |
| TIB | time in bed |
| TST | total sleep time |
| UCT | uncontrolled clinical trial |
| WASO | wake time after sleep onset |

that of a "standard" intervention such as stimulus control therapy (SCT) [7], as assessed through study design levels of evidence adapted from Sackett criteria [7,8]. Nevertheless, the review group and the AASM committee did conclude that "sleep restriction is effective and a recommended therapy in the treatment of chronic insomnia" [7, p. 1417].

Since the publication of the guidelines in 2006, behavioral interventions have shown further promise in controlled studies [4,9]. Recently, and salient to this review, Epstein et al. [10], conducted a dismantling study to compare multi component therapy (consisting of SRT and SCT with no structured cognitive therapy component), SRT, and SCT, to a waitlist control group. This study found SRT to be as effective as SCT and multi component therapy; suggesting SRT is a powerful standalone intervention. Earlier work also demonstrated that patient adherence to, and preference for SRT is more strongly associated with treatment outcome than other CBT-I components [11,12]. As a field, behavioral sleep medicine has encouraged broad dissemination of brief behavioral therapies [5,13–15], potentially as a "low-intensity" intervention within affordable stepped-care health-frameworks [16–19].

The aim of this review is to evaluate the evidence for the use of SRT in the treatment of chronic insomnia. It should be noted that we are referring in this review only to the therapeutic use of sleep restriction. We acknowledge that the term "sleep restriction" is more widely used in sleep science; usually in studies where healthy participants are experimentally exposed to a predefined (restricted) period of time in bed, to investigate the effects of sleep loss upon cognitive and physiological functioning [20,21]. Although not the focus of this review, closer reference to this experimental approach may be useful to aid understanding of both the acute effects and the therapeutic use of SRT for people with insomnia. Specifically, therapeutic SRT involves implementing a new prescribed sleep window (amount of total time allowed in bed) that initially matches the average total sleep time (from a one or two week sleep diary). Normally, for safety reasons, a minimum time in bed of no less than 4–5 h is used to protect against excessive daytime sleepiness. The sleep window is then titrated on a weekly basis through the use of average sleep efficiency scores from a weekly sleep dairy (see Table 1 for an example of the treatment guidelines) [5]. This is opposite to sleep compression therapy which uses a progressive and systematic reduction of time in bed to closely match sleep time/sleep need.

Our aim was to evaluate the evidence for the use of SRT in the treatment of insomnia. To achieve this aim, a systematic review of the literature was implemented. Suitable studies were then evaluated against a standardized quality assessment criteria [22] and levels of evidence (as per Sackett criteria [8]). Only studies that utilized SRT as a standalone intervention strategy for chronic insomnia, in accordance with SRT clinical guidelines [23] were included. Based on the evidence from the review, we conclude with a section regarding future directions to advance our understanding of SRT.

## Method

### *Criteria for inclusion of research articles*

This review aimed to include studies that were similar to the treatment delivery approach first described by Spielman et al. [1], This involves using the average total sleep time (from a one or two week sleep diary) to implement a new prescribed sleep window with the patient. More recently, a minimum time in bed of no less than 4–5 h is used to protect against excessive daytime sleepiness [3,5,24]. The sleep window is then titrated on a weekly basis through the use of average sleep efficiency scores from a weekly sleep dairy (see Table 1).

Online databases Web of Knowledge, PubMed, and Scopus were searched from 1986, one year before the publication of the SRT guidelines by Spielman et al. [1], until the end of October 2012. The search was re-run in August 2013 to take account of subsequent studies available online. The review used a subject and text word strategy with "insomnia" and "sleep restriction" or "sleep compression" (which is a systematic reduction of time spent in bed to closely match total sleep time/sleep need) as the primary search terms. Sleep compression therapy was included so that we would not miss any potentially relevant studies that may have applied a form of SRT. If the titles were appropriate and included any of the following terms: "insomnia", "behavior", "treatment" the online article was accessed and the abstract reviewed. Only full text articles were included and any published conference abstracts were omitted. If the abstracts were deemed suitable (for example, described a standalone intervention involving the curtailment of time in bed for the treatment of chronic insomnia), a full copy of the article was acquired and assessed for inclusion in this review (see Fig. 1). Studies were then considered for inclusion if they: a) implemented a standalone form of sleep restriction therapy; b) examined response to sleep-wake outcome

**Table 1**
Titration guidelines for sleep restriction therapy.

| Sleep efficiency scores (SE) | | |
|---|---|---|
| SE < 85% | SE ≥ 85% or <90% | SE ≥ 90% |
| Decrease TIB by 15 min | No change | Increase TIB by 15 min |

Displays the recommended titration guidelines for sleep restriction therapy from Spielman et al. [5]. SE: sleep efficiency = (average total sleep time ÷ average time in bed from sleep diary) × 100; TIB: time in bed.

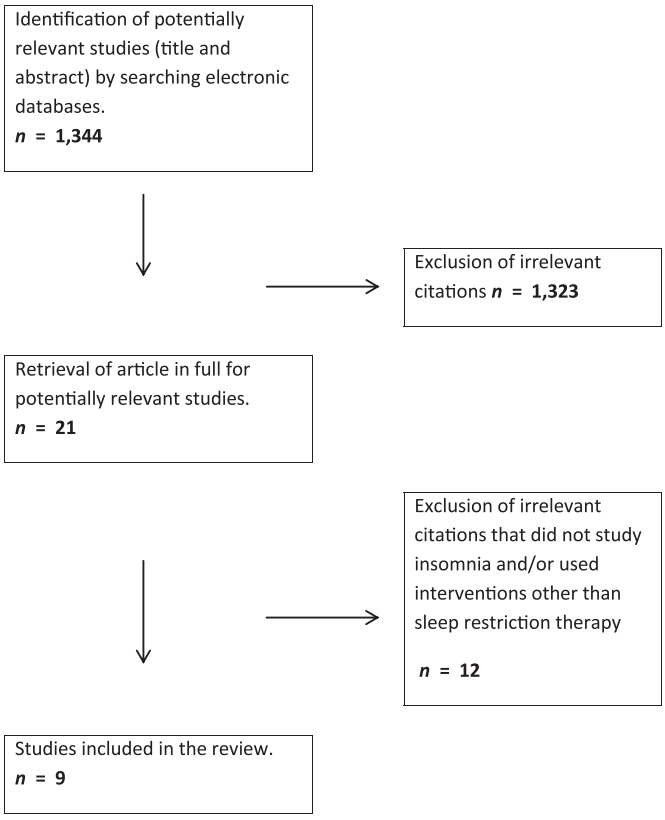


**Fig. 1.** Flowchart showing the process of selecting studies included in the review.

variables in a systematic manner (including uncontrolled clinical trials and case studies); c) included adult populations (≥18 y old); d) were published in the English language. Reviews, duplicates and studies that implemented sleep compression therapy or SRT as a treatment package (CBT-I), were excluded (see Fig. 1). The reference sections of all retrieved articles were also searched to further identify suitable studies for inclusion.

Standardized quality assessment criteria [22] (see Appendix A) were applied to provide structure to the review process. The quality of a study is defined in terms of the extent that design, conduct, and analyses minimized errors and biases for both randomized controlled trials (RCT) and controlled trials. This yields a global score for each study, and so enabling comparisons to be made across trials. Thus, the overall quality score enables a consistent assessment of evidence and quality of available medical research studies [22]. This approach normally involves appraisal of 14 items (study; objective, design, method, subjects, intervention, blinding investigator and subject, outcome, sample size, analytic methods, variance, confounds, description and conclusion), on a three-point rating scale (yes = 2, partially = 1, and no = 0). However, one item (relating to blinding of the investigators to treatment) was removed as this was not applicable to the present review. The items are consistent with the recommendations from the Centre for Reviews and Dissemination for systematic reviews [25] and in line with the previous study assessment approach by the AASM [2]. Item scores are summed and a percentage is given to each study (see Table 2). For each study, we report this overall score to gauge study quality [22], the study design and evidence level (using the Sackett system [8] as per the previous AASM practice parameters) [6,7,26,27]. The Sackett system [8] grades evidence levels through the following criteria: randomized well designed trials with low alpha and beta error (grade I), randomized trials with high alpha and beta error (grade II), nonrandomized concurrently controlled studies (grade III), nonrandomized historically controlled studies (grade IV), case series (grade V). Single case studies were not assigned any evidence level. Only studies that met grade III evidence or above were examined further for SRT outcome data. This is considered the minimum level of evidence for the AASM to recommend psychological treatments for insomnia as either a "standard" or "guideline patient care option" [6,7,28].

The primary outcome data are based on sleep diary continuity variables: sleep onset latency (SOL), wake time after sleep onset (WASO), sleep efficiency (SE: total sleep time ÷ time in bed × 100). Secondary variables reported include: total sleep time (TST), number of awakenings (NOA), total time in bed (TIB), and subjective ratings of sleep quality (SQ) (see Table 2). This approach has been used previously to provide a common mode of assessment for different insomnia interventions [29]. The primary outcome variables of the surviving studies were then analyzed through the use of effect size (ES) scores. Effect size uses standard deviation units to provide a measure of change; these are defined as small (0.2), medium (0.5) and large (>0.8) [30]. The overall weighted effect size was calculated by the formula ($\sum[di^*N]/\sum[N]$), where *di* is the effect size of the individual study [31]. The effect sizes were weighted to account for individual sample sizes. This methodology has been used to evaluate response to insomnia treatments [29,31].

## Results

### *Description of studies included in the review*

The initial and updated electronic database search yielded 1344 (WEB OF KNOWLEDGE = 664, PubMed = 445, SCOPUS = 235) potentially relevant studies combined; after reading titles and then abstracts of these studies, 21 were deemed adequate and a full version of the article was acquired. From these 21 studies, nine fulfilled the inclusion criteria (see Fig. 1). Twelve studies were excluded for the following reasons: two did not study insomnia [32,33]; four used sleep compression therapy [34–37]; two used multi component therapy [11,38]; one implemented a form of sleep compression therapy [39]; and finally, three studies were preliminary reports of subsequently reported data and were not included in this review [40–42]. The following sub-sections report an overall audit of these initial studies (see Table 2).

### *Design/randomization/controls*

Of the nine studies found in the literature search, four implemented randomized controlled trials [10,43–45], one was a non-randomized controlled trial (NRCT) [46], three were uncontrolled clinical trials (UCT) [1,47,48] and one was a case study [49]. Out of the four RCTs, all used well-defined randomization procedures [10,43–45]. Adequate control groups (waitlist controls, matched for therapist time and/or a comparison to another CBT-I intervention) were used in the majority of both the randomized and controlled trials (see Table 2).

### *Participants/power/sample*

Of the nine included studies, seven treated participants with primary insomnia [10,43–48] (this was either specified by research diagnostic criteria [50] or was ascertained from the methods sections of the studies), and two treated those with co-morbid insomnia [1,49]. Three studies employed lab-based polysomnography (PSG) to exclude occult sleep disorders prior to testing [1,44,48]. The average participant age (and standard deviation) across the nine studies was found to be 55.3 y (10.2) (see Table 2). Three studies sampled older adults only (60 y+) [10,44,46]. One study had sufficient power (≥30 participants in each arm) to detect a medium-to-large treatment effect, as per previous power calculations [10]. The remaining nine

**Table 2**
Description of studies included in the review of sleep restriction therapy for insomnia.

| Author(s) (y) | Design and level of evidence | Treatment type | Enrolled participants | Sleep outcome(s) | Summary of findings at post-treatment | Summary of findings at follow-up | Assessment quality score (%) |
|---|---|---|---|---|---|---|---|
| Bilwise et al. (1995) [46] USA | NRCT; III | SRT vs. relaxation therapy | 32 elderly adults (mean age = 68.7 y) with primary insomnia | Sleep diary data | SOL ↓ for SRT & RT ($p < .01$). No significant Δ in TST. | 3 mo: SOL maintained and TST ↑ ($p < .001$). | 19 out of 26 (73.1%) |
| Epstein et al. (2012) [10] USA | RCT; I | SRT vs. SCT vs. multi-component behavioral intervention vs. wait-list control | 179 older adults (mean age = 68.9 y) with primary insomnia | Sleep diary data, actigraphy and the ISI. | Sleep diary compared to waitlist controls: SOL ↓, WASO ↓, TST ↑, SE ↑, SQ↑ (all $p < .01$). Actigraphy: TST no Δ, SOL ↓, WASO ↓, SE ↑ (all $p < .01$). ISI ↓ ($p < .05$). | All gains maintained at 3 mo and 12 mo. | 23 out of 26 (88.5%) |
| Fernando et al. (2013) [43] NZ | RCT; II | SRT vs. sleep hygiene instructions | 45 adults (median age = 58 y) with primary insomnia | Telephone response regarding sleep quality. | The SRT group benefitted significantly better than the SHE group for sleep quality ($p < .05$). | N/A | 23 out of 26 (88.5%) |
| Friedman et al. (2000) [44] USA[a] | RCT; II | SRT & sleep hygiene instructions vs. NSRT & sleep hygiene instructions vs. sleep hygiene instructions | 39 older adults (mean age = 64.2 y) with primary insomnia | Telephone sleep diary data, PSG and MSLT (sub-sample $n = 19$ at baseline, treatment end, and 3 mo follow-up), actigraphy and the SSS. | Sleep diary: SE ↑ ($p < .05$). Actigraph: TST ↓ ($p < .05$). PSG and MSLT: means and standard deviations only reported due to small sample size. | 3 mo: sleep diary: SE maintained. No Δ in actigraphy. SSS for SRT & SHE ↓ ($p < .05$). | 22 out of 26 (84.6%) |
| Kyle et al. (2011) [47] UK | UCT; V | SRT only | 18 adults (mean age = 42 y) with primary insomnia | Sleep diary data, qualitative voice recordings, ISI, PSQI, GSES | SOL ↓, WASO ↓, SE ↑, SQ↑, (all $p < .01$). No Δ in TST. ISI ↓, PSQI ↓, GSES ↓, (all $p < .001$). | 3 mo: all gains maintained and TST ↓ ($p < .01$). | 16 out of 26 (61.5%) |
| Kyle et al. (2013) [48] UK | UCT; V | SRT only | 16 adults (mean age = 47.1 y) with primary insomnia | Sleep diary data, PSG, ISI, ESS, GSES, PVT | Sleep diary: SOL ↓, WASO ↓, SE ↑ (all $p < .05$). No Δ in TST. PSG: TST ↓ ($p < .001$). ISI ↓ ($p < .001$). No Δ in ESS. PVT: attentional lapses ↑, reaction times ↑ (both $p < .05$). | 3 mo: sleep diary: All gains maintained and TST ↑ ($p < .05$). | 19 out of 26 (73.1%) |
| Morin et al. (1990) [49] USA | CS | SRT only | 1 female (49 y-old) with comorbid insomnia | Sleep diary data and hourly hospital staff reports | 27 d: TST ↑. | 16 wk: TST ↑. | 8 out of 26 (30.8%) |
| Spielman et al. (1987) [1] USA | UCT; V | SRT only | 49 adults (mean age = 46 y) with chronic insomnia | Sleep diary data, PSG (screening only in a sub-sample of 31), 13 ISQ | Sleep diary: TIB ↓, SOL ↓, WASO ↓, TST ↑, SE ↑ (all $p < .05$), ISQ ↓. | 9 mo: improvements maintained ($n = 23$, no ISQ follow-up). | 16 out of 26 (61.5%) |
| Taylor et al. (2010) [45] USA | RCT; II | SRT & hypnotic withdrawal vs. Sleep hygiene instructions | 46 adults (mean age = 53.7 y) with chronic insomnia | Sleep diary data & reported use of hypnotics. | SRT + HW compared to SHE: SOL ↓ ($p < .05$), WASO ↓ ($p = .052$), SE ↑ ($p < .05$), No difference in TST. Hypnotic use ↓ ($p < .001$) compared to SHE: SOL ↓ ($p < .05$), WASO ↓ ($p = .05$), SE ↑ ($p < .05$), No difference in TST. Hypnotic use ↓ ($p < .001$) compared to SHE. | 6 mo (for SRT + HW only): all gains maintained and TST ↑ ($p < .001$). All gains at 6 mo maintained at 12 mo. | 22 out of 26 (84.6%) |

Displays an overview of each study included in the review process. CS: case study; ESS: Epworth sleepiness scale; GSES: Glasgow sleep effort scale; HW: hypnotic withdrawal; ISI: insomnia severity index; ISQ: insomnia symptom questionnaire; MSLT: multiple sleep latency test; NOA: number of awakenings; non-randomized control trial; NRST: nap modification sleep restriction therapy; PSG: polysomnography; PSQI: Pittsburgh sleep quality index; PVT: psychomotor vigilance task; RCT: randomized control trial; RT: relaxation therapy; SE: sleep efficiency; SHE: sleep hygiene education; SOL: sleep onset latency; SSS: Stanford sleepiness scale; SQ: sleep quality; SRT: sleep restriction therapy; TST: total sleep time; UCT: uncontrolled trial; WASO: wake time after sleep onset.

[a] Only the sleep restriction therapy group was included in the meta analysis section of this review for this study.

studies may have high false-positive and/or high false-negative errors due to low statistical power.

*Post-treatment assessments*

Post-treatment assessments were carried out at three [10,44,46–48], four [49], six [45] and nine months post treatment [1]. Two studies also re-assessed gains at 12 mo post-treatment [10,45].

*Study evaluation and assessment*

Next, for comparison an evaluation criterion (see Appendix A) was applied to all of the nine studies. Overall study quality scores varied considerably (mean: 18.7; range: 8–23, out of 26; see Table 2). All studies were assessed independently by two reviewers (CBM & another post-graduate level researcher). Inter-rater reliability was found to be fair (Cohen's kappa = 0.22). Discrepancies in assessment were discussed and re-assessed by each reviewer resulting in greater reliability (Cohen's kappa = 0.60) [51]. Studies with grade III evidence and above (as per Sackett criteria) [8] were deemed to be adequate to examine the impact of therapy. Out of the nine studies, four met this criterion (average age = 63.9 y, standard deviation = 7.1) [10,44–46]. The following results examine the efficacy of these studies. Primarily, studies were deficient for sample size, randomization and for sufficient placebo controls. One RCT was not included as it did not report any primary sleep diary measures pre-to-post therapy [43].

*Post treatment sleep diary outcome measures*

Of the four studies with the minimum level of evidence (grade III and above), weighted ES scores were calculated to take account of individual sample sizes for sleep diary outcome variables (SOL, WASO, SE, TST, NOA, TIB, & SQ). These were calculated between post-treatment and baseline for the active SRT arm and the control condition. For the SRT arm, it was found that SOL decreased in all studies [10,44–46], the weighted ES for SOL was medium (0.64). Reductions for WASO were found in three of the four studies [10,44,45] as one did not report this [46]; the weighted ES was large (1.36). Sleep efficiency increased in three studies [10,44,45] one study failed to report this [46]; the mean weighted ES for SE was also large (1.5). Secondary pre-to-post measures of sleep diary variables (TST, NOA, TIB, and SQ) were also compared at post-treatment to baseline levels. This revealed a small increase in TST (ES = 0.3), NOA was not reported in any of the four studies, whereas a large reduction in TIB was reported in two studies (weighted ES = 1.26), and finally SQ ratings were only reported in one study and were found to increase (ES = 0.3) (see Table 3) [10]. The control condition did not reveal significant improvements across the studies. Although SOL, WASO and TIB all decreased (ES = 0.06, 0.01 and 0.3 respectively) and SE, TST and SQ all increased (ES = 0.04, 0.01 and 0.03 respectively).

*Objective sleep outcome measures*

For objective outcome measures, statistical differences in objectively-defined sleep variables were not tested in the one study that employed PSG pre-to-post SRT. This was due to the small number of participants who underwent PSG testing ($n = 6$) [44]. The same study also used the multiple sleep latency test (MSLT) but again only in the same sub-group of participants [44]. Two studies evaluated actigraphy data as an outcome measure; one found a decrease in SOL, WASO, and an increase in SE compared to a waitlist control [10], with no further changes at the three month and one year follow-ups. TST did not change [10]. The other study revealed a decrease in TST at post-treatment but was underpowered, based on a previous power calculation [10] to test any interaction effects [44].

*Sleep related questionnaire outcome measures*

Overall, from the nine studies profiled in this review, pre-to-post decreases on subjective questionnaire measures were

**Table 3**
Effect size scores for the five studies with sufficient methodological strength at post-treatment compared to baseline.

| Subjective sleep outcome measure (sleep diary) | Pretreatment value | | Posttreatment value | | Pre-to-post treatment change | | Number of studies | Number of participants | Weighted effect size[a] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Value | % | | | Mean | SD |
| *Sleep latency (min)* | | | | | | | | | | |
| Sleep restriction therapy | 42.15 | 37.50 | 22.81 | 19.65 | −19.34 | 46 | 4 | 98 | 0.64 | 0.37 |
| Control | 41.32 | 29.43 | 37.68 | 24.14 | −3.64 | 9 | | 94 | 0.06 | 0.36 |
| *Wake time after sleep onset (min)* | | | | | | | | | | |
| Sleep restriction therapy | 72.98 | 39.04 | 30.81 | 23.78 | −42.17 | 58 | 3 | 82 | 1.36 | 0.42 |
| Control | 66.62 | 38.31 | 55.32 | 30.28 | −11.30 | 17 | | 78 | 0.01 | 0.55 |
| *Sleep efficiency (%)* | | | | | | | | | | |
| Sleep restriction therapy | 66.60 | 13.02 | 82.88 | 8.78 | 16.28 | 24 | 3 | 82 | 1.50 | 0.35 |
| Control | 67.00 | 11.88 | 71.59 | 8.92 | 4.59 | 7 | | 78 | 0.04 | 0.23 |
| *Total sleep time (min)* | | | | | | | | | | |
| Sleep restriction therapy | 334.08 | 69.00 | 351.14 | 49.58 | 17.06 | 5 | 4 | 98 | 0.30 | 0.31 |
| Control | 335.80 | 68.60 | 341.93 | 55.56 | 6.13 | 2 | | 94 | 0.01 | 0.40 |
| *Number of awakenings* | | | | | | | | | | |
| Sleep restriction therapy | – | – | – | – | – | – | 0 | – | – | – |
| Control | – | – | – | – | – | – | | – | – | – |
| *Total time in bed (min)* | | | | | | | | | | |
| Sleep restriction therapy | 500.60 | 55.30 | 439.19 | 40.12 | −61.41 | 12 | 2 | 60 | 1.26 | 0.40 |
| Control | 509.60 | 51.40 | 489.98 | 45.32 | −19.62 | 4 | | 61 | 0.38 | 0.01 |
| *Sleep quality ratings* | | | | | | | | | | |
| Sleep restriction therapy | 2.77 | 0.50 | 2.90 | 0.38 | −2.39 | 86 | 1 | 44 | 0.30 | – |
| Control | 2.57 | 0.42 | 2.58 | 0.37 | 0.01 | 0 | | 50 | 0.03 | – |

Table displays effect size scores for the four studies with sufficient levels of evidence from the review. Control groups either consisted of wait-list controls, or were compared to another cognitive behavioral therapy intervention.

[a] Overall weighted effect size scores were calculated by the formula ($\sum[di^*N]/\sum[N]$), where *di* is the effect size of the individual study.

observed (e.g., insomnia severity index (ISI)) [10,47,48], insomnia symptom questionnaire (ISQ) [1], Pittsburgh sleep quality index (PSQI) [47], and the Glasgow sleep effort scale (GSES) [47]. Only one study with adequate methodological strength employed one of these instruments; a significant difference ($p < .01$) between the SRT and waitlist control condition was found with the ISI at post treatment (ES = 1.18) for the SRT group [10]. This study also quantified a treatment response rate using the ISI, whereby a response was defined as a change of six points from baseline to post-treatment and remission was considered if the post-treatment ISI score was <8 (no clinical insomnia) [10,52]. It was found that 50% of the SRT group ($n = 44$) responded to treatment and the remission rate was 22.7% [10].

### *Adverse effects of treatment and daytime functioning measures*

Adverse effects were profiled in two studies out of nine included in this review. One used a mixed methods approach (involving post-treatment semi-structured interviews, qualitative audio-diaries) [47]. Daytime functioning and health related quality of life outcomes were also included in this study and involved the daytime functioning and sleep attribution scale, the Glasgow sleep impact scale, the occupational impact of sleep questionnaire and the short-form health-survey 36. All measures were found to improve significantly at both four weeks and three months post treatment compared to baseline scores [47]. Another study used PSG, the psychomotor vigilance task (PVT) and subjective markers of sleepiness pre, during and post SRT. Sleep restriction therapy was initially found to be associated with substantially reduced objective TST, vigilance impairment on the PVT and increased daytime sleepiness via the Epworth sleepiness scale (ESS). Both the PVT and ESS were found to normalize at three months post treatment [48]. One further study also used the Stanford sleepiness scale (SSS) but this was underpowered to test for differences [44]. No other daytime functioning measures were reported in any of the trials.

### *Sleep restriction therapy instructions*

As a result of the literature search, it is important to also highlight that all of the nine assessed studies used a range of therapeutic guidelines for the implementation of SRT in comparison to the initial SRT procedures [1] (see Table 4) for an overview.

## Discussion

The primary objective of this review was to rigorously examine the evidence base for the use of single component sleep restriction therapy (SRT) in the treatment of insomnia. Nine studies met the initial inclusion criteria and were then assessed using standardized study assessment criteria [22]. Of these, four studies (three randomized controlled trials and one controlled trial) were considered eligible to evaluate the efficacy of SRT. The weighted effect size (ES) scores for sleep diary parameters (sleep latency; SOL, wake after sleep onset; WASO, and sleep efficiency; SE) were calculated. The majority of ES scores for sleep diary parameters were greater than 0.6, indicating medium-to-large treatment effects [30]. For total sleep time (TST), a small improvement was found by the end of treatment (weighted ES = 0.3), consistent with previous CBT-I studies [53–57]. Ratings of sleep quality were found to improve in the only study that reported these (ES = 0.3) [10]. For comparison, the weighted ES for the control condition did not reveal significant improvements across studies. For example, the weighted ES was extremely small for the following variables: SOL = 0.06, WASO = 0.01, SE = 0.04, TST = 0.01 and SQ = 0.03 (see Table 3).

From the four studies with adequate methodological strength, the results suggest that single component SRT is an efficacious insomnia treatment with moderate-to-large effects on sleep diary variables at post-treatment. There are several caveats and limitations with respect to these findings.

First, the current review found only nine studies evaluating SRT for insomnia disorder and just four that met our inclusion criteria, limiting the strength of the overall findings. Nonetheless, it is also important to consider the most recent American Academy of Sleep Medicine (AASM) practice parameters in 2006 that considered SRT as a "guideline" intervention, one step below that of stimulus control therapy (SCT) which is a "standard" intervention [7]. Since that time, five additional SRT studies have been published and included in this review [10,43,45,47,48], including one with level I evidence [10] and one with level II evidence [45] (as per Sackett criteria and the AASM classification of evidence) [6–8]. Overall, with four RCTs

**Table 4**
Description of sleep restriction therapy intervention types.

| | |
|---|---|
| Spielman et al., 1987 [1] | From a 2-wk sleep diary, a sleep wake schedule was prescribed. The average subjective TST was used to calculate the initial TIB. The time for rising was established first and then the time for retiring at night was set to equal the new prescribed TIB (none were prescribed <4.5 h). Changes to TIB were made to the sleep window through therapy via the following criteria over the previous 5 d: a) when the mean SE is ≥90%, then the TIB is increased by fifteen minutes – by setting the retiring time earlier. b) When the mean SE is <85% TIB is decreased to the mean sleep time of the previous 5 d. c) If the mean SE is <90% and ≥85%, then the time in bed is not altered. |
| Morin et al., 1990 [49] | Spielman et al., (1987) [1] + 4 h minimum time in bed. Achievement of high SE increased TIB. |
| Bilwise et al., 1995 [46] | Spielman et al., (1987) [1] + flexibility to TIB. |
| Friedman et al., 2000 [44] | Group 1: Spielman et al., (1987) [1] + TIB at the start of treatment and was not set strictly at the mean TST from baseline and was not reduced for failure to reach criterion + sleep hygiene. Group 2: same as group 1 plus participants were encouraged to take a 30-min daily afternoon nap between 13:00 and 15:00. Both groups were given weekly increments of TIB according to an algorithm (based on baseline diary data of TST and TIB) and also of subjective reported sleepiness. All subjects started with at least 5 h TIB but by the end of the fourth week TIB was increased to 7 h. Time in bed was only increased by going to bed earlier. |
| Taylor et al., 2010 [45] | Spielman et al., (1987) [1] + TIB = 10% above the average estimated TST reported for the previous week but no less than 5 h. Once SE = 90%, hypnotics were withdrawn (50% of dose for per week). |
| Kyle et al., 2011 [47] | Spielman et al., (1987) [1] + 5 h minimum TIB; if SE <85% then sleep window decreased by 15 min. |
| Epstein et al., 2012 [10] | Spielman et al., (1987) [1] + 5 h minimum TIB. |
| Fernando et al., 2013 [43] | No specific details given apart from participants received personalized instructions on bedtime and wake time routines. |
| Kyle et al., 2013 [48] | Spielman et al., (1987) [1] + 5 h minimum TIB; if SE <85% then sleep window decreased by 15 min. |

Displays an overview of the sleep restriction therapy implementation methods for each study included in the review process. TIB: time in bed; TST: total sleep time; SE: sleep efficiency.

and one NRCT, SRT now has sufficient evidence to be classified as an established "standard" treatment intervention as per the American Psychological Association (APA) task force report and recommendations: criteria for empirically validated treatments [58]. The APA criteria have been used previously by the AASM to quantify the evidence for psychological treatments for insomnia [2,6,7,26]. The AASM may wish to re-consider the evidence base for SRT, in light of this systematic review, and determine whether an upgrade in line with other CBT-I components, such as SCT and relaxation training is deserved. It is important to note that SCT obtained its "standard" status through five RCT's with level II evidence [6,26]. In the 2006 update, one further RCT (with level II evidence) was added to this [2,7]. When compared to SCT, SRT may not have been used as frequently as a standalone intervention, either because researchers and clinicians utilize multicomponent cognitive behavioral therapy (by way of both brief and full versions) [14,24,59–61] or use SRT in combination with CBT-I or brief behavior therapy. Until recently, the insomnia field has generally failed to dismantle individual components of CBT-I through RCT methodology [10].

The results of this review are comparable to previously published meta-analytic data for CBT-I sleep diary treatment outcome variables [53–57]. In particular, the weighted ES of the sleep variables (SOL, WASO, SE, and TST) resemble or are greater than those of CBT-I at post-treatment compared to baseline [31,54,57]. For example, Irwin et al. [57], and Okajima et al. [54], both found a medium mean ES reduction for SOL, a medium-to-large mean ES reduction for WASO and large mean ES increase for SE. This is in line with findings from the present review (weighted ES; SOL = medium reduction, WASO = large reduction, SE = large increase, only one study reported SQ ratings and found a medium ES improvement). Total sleep time was also found to improve at post-treatment, although the weighted effect size was in the small range (ES = 0.3). It may be that studies are unable to detect large changes in TST, longer follow-up times are required to examine robust changes in TST, or that different implementation methods of SRT affect treatment outcome. However, the ES for TST was also comparable to previous CBT-I meta-analytic data whereby Irwin et al. [57], discovered a 0.17 weighted ES increase for TST, Okajima et al. [54], found a mean ES increase of 0.32, and also Smith et al. [31], found a mean ES increase of 0.46 at post-treatment compared to baseline.

Objective measures of sleep-wake parameters are lacking in trials of SRT. Only one of the four studies with sufficient methodological strength attempted to measure in-lab objective sleep variables but this was underpowered to test for differences in both PSG and MSLT variables [44]. Actigraphy has been used marginally more, in two of the four studies with sufficient methodological strength [10,44]. One found a decrease in SOL, WASO, and an increase in SE compared to a waitlist control at post treatment only [10]. The other study found a decrease in TST at post treatment but was also underpowered to test for between group effects [44]. Actigraphy may be valuable in providing an objective marker of changes in sleep due to SRT and as a marker of adherence and implementation of therapy. Further objective (PVT) and subjective markers of sleepiness pre, during and post SRT were profiled in one uncontrolled study [48]. Participants also slept for three nights in the lab with PSG to profile sleep during therapy implementation (on days one, eight and 22). Sleep restriction therapy was initially found to be associated with substantially reduced objective TST, vigilance impairment (PVT) and increased daytime sleepiness (ESS). Both the PVT and ESS were found to normalize at three months post treatment. Healthy controls were employed to examine differences in vigilance performance data only. No baseline differences were found, suggesting the impact of SRT was contributing to the vigilance performance deficits [48].

For subjective questionnaire measures, studies found pre-to-post decreases in the ISI [10,47,48], ISQ [1], PSQI [47], and GSES [47]. However, no average ES data was examined for these outcomes as three studies with sufficient methodological strength [44–46] collected data prior to the development and validation of the ISI [62], GSES [63], and ISQ [64]. One study out of these four used the ISI pre-to-post treatment. Interestingly, the post treatment ES difference between the SRT group and the waitlist control group for the ISI was 1.18, similar to the SCT group (ES = 1.22) and the multicomponent therapy group (ES = 1.24) [10]. No studies with sufficient methodological strength used the PSQI as an outcome measure, perhaps as this is not specifically designed to evaluate insomnia [65]. Global measures of sleep symptomology (ISI & PSQI) are recommended measures and likely to change due to a treatment response from SRT [65]. In particular, the ISI may be the most useful for standardizing response and remission outcomes due to treatment [10]. One study removed from the review process as it was a preliminary report of a subsample of participants from Kyle et al. (2013) [48], measured subjective changes in mood and daytime functioning before and throughout SRT in nine patients with psychophysiological insomnia [41]. Changes in mood and cognition were profiled pre and during the first three weeks of SRT implementation using ecological momentary assessment, where the daytime insomnia symptom scale was completed at four defined points through the day [66,67]. Interestingly, measures of sleepiness/fatigue increased overall at week one of SRT but, by week four, decreased below baseline levels. Alert cognition, displayed a significant week by time-point interaction, whereby a reduction in alertness at bedtime was observed at week three, while morning rise-time alertness was improved. These data indicate that SRT moderates alertness and sleepiness in therapeutic ways [41].

With regards to study quality and methodological strength, it was found that only one of the nine studies [10] had sufficient power (≥30 participants in each arm) to be classed as grade I evidence [8]. This suggests that most studies included in this review may suffer from statistical error (Type I and/or Type II). Therefore, the approach by Epstein et al. (2012) [10] is an important contribution to the literature. Specifically, the authors were able to differentiate ES scores of SRT compared to multi-component therapy (consisting of SRT and SCT only), SCT and to a waitlist control. Importantly, the authors found no differences between single and multi-component therapy for sleep outcome measures (sleep diary and actigraphy). For example, medium-to-large ES improvements were found for SRT, SCT and multi-component therapy on sleep diary data (SOL, WASO, SE, TST and SQ). Therefore, this study suggests that SRT, SCT and multi-component therapy are comparable for efficacy on sleep diary and actigraphy outcomes. For participant screening, only three trials included overnight polysomnography screening in most subjects prior to enrollment to assess for other potential occult sleep disorders prior to therapy implementation [1,44,48]. Likewise for study follow-up times, only two studies re-examined outcomes after six months of SRT. These studies did find that initial gains in sleep diary variables (SOL, WASO, and TST) were maintained [10,45]. The lack of long term follow-up data across all of the studies makes it difficult to evaluate long term outcomes of SRT and further trials are required with sufficient follow-up times. Large samples of participants are also required to achieve grade I evidence. Such adequately powered studies will help to avoid any type I or II statistical errors and will provide definitive evidence for SRT.

With respect to participant demographics, the mean participant age for the nine studies was found to be 55.3 y (see Table 2), although three studies specifically sampled participants aged 60 y and above. However, from the four studies with adequate methodological strength the mean age was found to be 63.9 y. This may be considered a limitation to the generalizability of the findings of this review and further SRT studies need to be conducted across different age groups in order to determine whether SRT may be more or less beneficial depending on patient age. It must be noted,

however, that multicomponent CBT-I studies have not found age to be a predictor of treatment response [2,26].

The delivery of SRT can also vary between studies making it difficult to compare SRT interventions directly. For example, one common variant of the SRT approach is the minimum time in bed which has changed as the literature has progressed (see Table 4). It is common to spend no less than five hours (six hours in vulnerable patients) time in bed as part of CBT-I procedures [3]. This guideline has developed to guard against negative consequences associated with extreme sleepiness with a reduction of time in bed [20]. For example, in the initial SRT study, 14 out of the 49 enrolled participants dropped out after a mean period of 19 d [1]. Adherence to SRT guidelines is known to be extremely difficult and has previously been examined [39]. Naps or lying down are generally not permitted until prescribed bed-time has been reached (except where explicitly integrated into a modified SRT). Studies have so far looked to vary the SRT procedures to include naps in order to aid adherence to therapy but have so far failed to rigorously test naps as countermeasures. One study attempted to evaluate adherence by encouraging older adults to nap in one of the two SRT treatment arms [44]. However differences were not observed between the two conditions, perhaps limited by the small sample size in each group (SRT $n = 16$, Nap SRT $n = 12$) [44]. In addition, the newly prescribed sleep-wake schedule must be maintained and adhered to everyday of the week until the next weekly meeting with the therapist where it is then re-examined. This is often a form of negotiation with the participant but has received little attention in the literature. The reduction of time in bed has also been suggested in the literature [5] but this remains to be formally evaluated. Future comparative studies of treatment procedures are required to test the effectiveness of the guidelines set out by Spielman et al. [5], for optimal treatment delivery. Once this has been achieved then standardization of therapy guidelines may take place.

*Based on the results of our review we suggest the following research directions to advance clinical understanding of SRT.*

1) *Study design and measures of sleep*: future well-controlled studies are required with grade I evidence, like that of the recent Epstein et al. [10] trial. Studies should also look to include objective assessments of sleep (actigraphy and PSG) in an effort to understand treatment effects further. This would enable the evaluation of acute and chronic changes in objective sleep parameters. For example, one recent meta-analysis of PSG-defined sleep parameters found evidence of objective sleep continuity disruption and reduced time spent in rapid eye movement (REM) and slow wave sleep (SWS), relative to controls [68]. The extent to which these parameters normalize through SRT is worthy of future research attention. Changes in sleep electroencephalography (EEG) power densities remain relatively untested. Previously, one CBT-I treatment study found a more rapid decline of EEG delta power in insomnia participants after therapy compared to placebo controls [69]. Sleep architecture has also been shown to change due to non-pharmacologic treatment of insomnia. For example, increased stage two, REM and SWS durations have been reported after effective CBT-I [70]. Future studies should test for specific SRT-related changes in the continuity and proportion of objectively defined sleep, as well as changes in the microstructure of sleep.

With respect to insomnia assessment, studies now need to adequately screen and measure insomnia before, during and at follow-up, in line with standard research guidelines for insomnia [50,65]. It is also currently unknown if SRT is efficacious for co-morbid insomnia as this remains to be formally evaluated. For example, moderate-to-large treatment gains as a result of SRT in those with insomnia with medical and psychiatric comorbidities would be in line with previous CBT-I outcomes [71].

2) *Measures of daytime functioning*: Examination of daytime functioning in SRT studies is severely lacking. Daytime impairment is an important aspect to consider given that the diagnosis of insomnia is dependent upon this complaint [61,72]. Further, it is this impairment that drives help-seeking behavior and makes insomnia a 24 h problem [72,73]. An improvement in this area would be expected as part of any treatment response. Future studies should specifically test for improvements in measures of daytime functioning, using appropriate [74] and recommended measures [65,72].

3) *Adverse effects and contraindications of therapy*: adverse effects were profiled in two studies that were assessed as part of this review process [47,48]. One used a mixed methods approach (involving post-treatment semi-structured interviews, qualitative audio-diaries, and questionnaire assessments) [47]. The other used objective (PVT) and subjective (ESS) measures of daytime sleepiness throughout therapy [48]. However, the majority of previous studies have thus far failed to adequately measure and profile any potential side effects or daytime impairment of SRT or CBT-I for that matter [75]. Further studies specifically testing initial daytime impairments and adverse effects of SRT are required, particularly during the acute period of therapy, where the effects of sleep restriction are likely to be most pronounced [41,48]. Such detailed profiling may help shed light on the relationship between adverse effects, treatment response and patient attrition. It is also important to consider that SRT may be contraindicated in specific subsamples of patients, where restricted sleep opportunity may stimulate negative outcomes. For example, SRT may trigger mania in bipolar disorder, lower the seizure threshold in those with seizure disorders such as epilepsy or exacerbate patients with excessive daytime sleepiness [71]. SRT-"light" or fixed bed and rise times may be effective alternatives to SRT in these patients [76].

## Conclusions

The primary objective of this review was to evaluate the evidence for the use of single component SRT in the treatment of chronic insomnia. Out of the nine studies included in this review, four were deemed adequate to fully evaluate the impact of SRT. It can be concluded that SRT is an effective single behavioral intervention for the treatment of insomnia for sleep diary variables. Thus, in light of this review, the AASM may wish to re-consider the status of SRT, to determine whether a clinical guideline upgrade is required. Results may be limited due to studies using slightly different SRT implementation strategies. Further research is required to systematically examine the clinical effectiveness of SRT through well designed large scale randomized controlled trials. Attention should be placed on further measures of subjective daytime functioning and of objective sleep changes.

**Practice points**

1. Single component SRT for insomnia is efficacious for the treatment of insomnia for primary sleep diary measures (SOL, WASO, SE and TST). The AASM may wish to re-evaluate the status of SRT.
2. A number of studies utilized various and different methods in the delivery and titration of SRT. As a result, studies should look to test the SRT guideline recommendations by Spielman et al. [5], for effectiveness. Standardization of the SRT guidelines may then take place.
3. There is currently little evidence to suggest that single component SRT improves daytime functioning and quality of life in insomnia. Further data is required to evaluate if daytime functioning improves as a result of SRT.

**Research agenda**

1. To implement randomized controlled trials to establish the clinical effectiveness of the SRT guidelines by Spielman et al. [5], in line with previous insomnia research recommendations.
2. To evaluate the initial minimum amount of time in bed required for a treatment response.
3. To further examine potential daytime consequences (impairments and/or improvements) of treatment through questionnaire measures in controlled experimental studies.
4. To profile changes in the proportions of PSG-defined sleep staging and the power spectral analysis of sleep in response to SRT.

## Acknowledgments

This research was supported by the National Health and Medical Research Council (NHMRC, Australia) Centre for Integrated Research and Understanding of Sleep (CIRUS), grant no. 571421; the Sackler Institute of Psychobiological Research (University of Glasgow Sleep Centre, Scotland, UK); and the Chief Scientist Office (Scotland, UK) Grant # CZG/2/503. Authors Epstein, Friedman and Pigeon are employees of the United States Department of Veterans Affairs, which supported their work on this manuscript. The authors' views or opinions do not necessarily represent those of the Department of Veterans Affairs or the United States Government.

## Appendix A. Checklist for assessing the quality of quantitative studies.

| Question | Criteria | Yes (2) | Partial (1) | No (0) | N/A |
|---|---|---|---|---|---|
| 1 | Question/objective sufficiently described? | | | | |
| 2 | Study design evident and appropriate? | | | | |
| 3 | Method of subject/comparison group selection or source of information/input variables described and appropriate? | | | | |
| 4 | Subject (and comparison group, if applicable) characteristics sufficiently described? | | | | |
| 5 | If interventional and random allocation was possible, was it described? | | | | |
| 6 | If interventional and blinding of investigators was possible, was it reported? | | | | |
| 7 | If interventional and blinding of subjects was possible, was it reported? | | | | |
| 8 | Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/misclassification bias? means of assessment reported? | | | | |
| 9 | Sample size appropriate? | | | | |
| 10 | Analytic methods described/justified and appropriate? | | | | |
| 11 | Some estimate of variance is reported for the main results? | | | | |
| 12 | Controlled for confounding? | | | | |
| 13 | Results reported in sufficient detail? | | | | |
| 14 | Conclusions supported by the results? | | | | |

Appendix A displays checklist for assessing the quality of quantitative studies from Kmet et al. [22]. Question number 6 was omitted from this review process as it was considered not applicable to this review process.

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